HAZARD MITIGATION SURVEY TEAM REPORT

for

The Nisqually Earthquake
February 28, 2001
DR-1361-WA

Federal Emergency Management Agency

Washington Military Department Emergency Management Division

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EXECUTIVE SUMMARY

On February 28, 2001, an earthquake of magnitude 6.8 struck the Puget Sound area of Washington State. The epicenter was located approximately 50 miles south of Seattle and 11 miles northeast of Olympia in an area locally known as the Nisqually Delta.

On March 1, 2001, President George W. Bush declared six counties in western Washington eligible to receive federal disaster assistance for damages due to the earthquake under DR-1361-WA. Over the following months, 18 more counties were added to the declaration, bringing the total number of counties declared eligible for federal assistance to 24. All counties in the State of Washington were automatically made eligible for Hazard Mitigation assistance with the disaster declaration.

Hazard Mitigation Surveys are performed immediately following the declaration of a disaster to identify: 1) hazard evaluation and mitigation measures that must be incorporated into the recovery process; 2) possible measures for funding under the Hazard Mitigation Grant Program or other disaster assistance programs; and 3) issues for inclusion in the state hazard mitigation plan.

To accomplish the Surveys, a Hazard Mitigation Survey Team was formed, consisting of the Federal Emergency Management Agency and representatives from other federal, state, tribal, and local governments. Three meetings were held in Olympia, Everett, and Yakima to identify issues and recommendations for actions in the following areas:

- Building codes
- Earthquake disaster information
- Earthquake preparedness
- Critical lifelines
- Critical facilities
- Seismic safety commission
- Earthquake loss estimates
- Incentives for seismic upgrades
- Long-term planning

This report identifies short- and long-term earthquake issues and provides information and direction for future revisions to the Washington State *Hazard Mitigation Strategy*. The recommendations developed by the Hazard Mitigation Survey Team are wide-ranging, yet all share the necessity for a coordinated, multi-objective approach to mitigation among local, state, tribal, and federal agencies and officials.

Appendices to this report provide a glossary, a list of acronyms and abbreviations used, Hazard Mitigation Survey Team participants, and report team members.

INTRODUCTION AND PURPOSE

A. Introduction

At 10:54 am PST, February 28, 2001, an earthquake of magnitude 6.8 (lasting as long as 45 seconds) struck the Puget Sound area. The epicenter was located approximately 50 miles south of Seattle and 11 miles northeast of Olympia, in an area locally known as the Nisqually Delta. The earthquake caused damage throughout Puget Sound and into areas of eastern Washington.

On March 1, 2001, President George W. Bush declared six counties in western Washington eligible to receive federal disaster assistance for damages caused by the Nisqually Earthquake. Over the following two months, 18 more counties were added to the declaration, bringing the total number of counties declared eligible for federal assistance to 24. The Federal Emergency Management Agency (FEMA), state and local agencies, and private relief organizations provided immediate assistance under FEMA DR-1361-WA.

The authority for development of this report is derived from the 44 CFR (Code of Federal Regulations). Hazard Mitigation Surveys are performed immediately following the declaration of a disaster to identify: 1) hazard evaluation and mitigation measures that must be incorporated into the recovery process; 2) possible measures for funding under the Hazard Mitigation Grant Program (HMGP) or other disaster assistance programs; and 3) issues for inclusion in the state hazard mitigation plan.

Hazard Mitigation Survey Teams (HMST) consist of FEMA and other federal agency representatives, state agency representatives, and local and tribal government representatives. The specific agencies involved depend on the type of disaster. Members of the HMST for DR-1361-WA are listed in the Appendices.

Three HMST meetings were held during the last week of April 2001, in Olympia, Everett, and Yakima. These meetings drew on the specialized knowledge and expertise of people from a variety of federal, state, tribal, and local agencies. The participants identified issues and recommendations for actions in the following areas: building codes, earthquake disaster information, earthquake preparedness, critical lifelines, critical facilities, seismic safety commission, earthquake loss estimates, incentives for seismic upgrades, and long-term planning.

B. Purpose

The HMST Report is intended to provide guidance to all the agencies involved in recovery, reconstruction, and mitigation following a disaster. Its purpose is to identify actions that will reduce the potential for future earthquake losses using sustainable methods. Recommendations presented in this report will be implemented in a timely manner under the direction of the appropriate agencies and jurisdictions so that communities at risk in Washington will be better prepared for future, possibly more destructive, earthquakes.

This HMST Report builds on the information and strategies presented in the *Early Implementation Strategy* (EIS) Report released March 2001 (see page 17 for a summary of the EIS). This report will also identify short- and long-term earthquake issues, providing information and direction for future revisions to the Washington State *Hazard Mitigation Strategy*.

The long-term recovery period after a disaster, such as the Nisqually Earthquake, can actually lead to the creation of better communities. From previous experiences, we know that hazard mitigation efforts can improve a community's resistance to disaster. But when mitigation planners and implementers broaden their thinking beyond disaster recovery to multi-disciplinary solutions, the recovery process may also improve business opportunities, protect the natural environment, involve and support diverse populations, manage growth, and preserve the community's history, culture, and other special attributes for future residents.

Collectively, these represent ideal, but not immediately accomplishable, goals. Mitigation is an incremental process. One particular mitigation effort may be able to take only a small step toward a goal. Whatever solutions can be achieved will make a significant difference in a community, and will set a precedent (raise the bar) for future efforts. This is the process of developing a more sustainable community.

Fortunately, this is a time when mitigation planners and implementers can take advantage of all the social research, evaluation, and visionary thinking that has been done in recent years to define and promote the concepts of sustainability as it applies to communities. A sustainable community is defined not so much by a single description as it is by a collection of practices. A sustainable community:

- Fosters a commitment to work together to solve problems and focus on stability;
- Enhances the ability of the community to withstand and recover from natural disasters;
- Adopts an integrated approach to develop supportive partnerships;
- Acts as steward of the environment for the long-term economic benefit of both the present community and future generations; and
- Promotes equal participation in decision-making.

Last year, FEMA adopted its Post-Disaster Sustainability Mission Statement:

> *To promote and facilitate sustainable development at the local level by integrating the principles and practices of sustainable development into the broader goals of the post-disaster recovery process. This is accomplished in partnership with the state, and in coordination with other federal agencies, local agencies, and non-governmental organizations.*

As a part of this disaster's overall mitigation strategy, state, tribal, and local governments are encouraged to implement the principles of sustainable redevelopment beyond the recovery process. The intent is to promote an integrated and balanced approach between economic, environmental, and social interests that will result in multi-purpose improvements in the community's development after the disaster.

Sustainable (ideal and long-range) goals specific to this earthquake include the following:

- Avoid rebuilding damaged areas (sites) that will not correct existing potential hazard problems, or that will expose the community to damage in future disasters.
- Integrate hazard mitigation considerations with the community's economic prosperity, social environment, and ecological integrity in the long-term recovery process.
- Support response and recovery approaches that are consistent among federal, state, tribal, and local governments.
- Encourage restricted development, or development alternatives, for areas of severe seismic risk.
- Promote updating seismic building codes to the most current National Earthquake Hazard Reduction Program (NEHRP) recommended provisions.

Thus, instead of just rebuilding and re-establishing prior conditions, many local jurisdictions may have the unforeseen opportunity to improve their housing, transportation, land use, hazard reduction programs, recreation, or other social amenities during the process of recovering from the earthquake.

In summary, the awareness, energy, and resources that Washington communities bring to the task of recovering from a disaster can serve as a catalyst for important discussions that will contribute to the broader community objectives of livability and sustainability.

BACKGROUND

A. Seismic Safety Advisory Committee

The Seismic Safety Advisory Committee (SSAC) was established in 1991 to develop a comprehensive plan and make recommendations to the Legislature for improving the state's earthquake preparedness. The SSAC was comprised of representatives from state and local agencies, professional organizations, and representatives from the private sector who had an interest in improving seismic safety in Washington. Their report, *A Policy Plan for Improving Earthquake Safety in Washington – Fulfilling Our Responsibility*, was issued December 1, 1991.

The goals of SSAC were to:

- Assess the seismic risk in the state.
- Determine the status of risk mitigation, preparedness, and response capabilities.
- Clarify and determine federal, state, and private roles with respect to each strategy and initiative.
- Identify needs for additional information, mitigation, preparedness, and response capabilities.
- Develop and prioritize state strategies and initiatives.
- Propose and prioritize policy-level actions.

The overall approach of the committee was based on the principle that improving seismic safety in Washington is a long-term proposition. It required the crafting and nurturing of a continuous multi-year program. The work program focused on the following key elements:

- Identification of the current status of seismic mitigation;
- Development of policy recommendations; and
- Identification of implementation strategies.

The SSAC reviewed the status of the readiness for an earthquake in Washington. What they found is cause for concern: while some organizations and individuals are prepared, most are not. The following list summarizes their findings:

- Emergency response capacity will be overwhelmed.
- Schools are a cause for concern.
- Fire and medical services are vulnerable.
- Transportation lifelines are not secure.
- Utilities have not addressed seismic risk.

The following were the top priority recommendations for action:

- Provide seismic safety oversight
  - Create, by legislation, an interagency seismic safety policy committee.
- Improve emergency planning
  - Conduct a state-level review of emergency communication systems and implement the review recommendations.
  - Clarify the liability law for volunteer emergency workers and implement a central registry of trained emergency worker and volunteer personnel.

    - Prepare and implement a multi-media awareness and education program.
    - Provide standardized materials to help local jurisdictions to more effectively train personnel.
    - Standardize planning guidelines for local jurisdictions as part of ongoing emergency planning.
    - Increase awareness of structural and non-structural earthquake hazards as part of ongoing education.
- Strengthening buildings
    - Assess the seismic vulnerabilities of school facilities and improve seismic safety as part of long-range capital planning.
    - Develop and submit amendments to the State Building Code Council that require seismic strengthening during planned remodeling projects.
    - Support the review of current Uniform Building Code Seismic Zone 3 boundaries.
    - Develop financial incentive programs to assist with seismic strengthening projects.
    - Support and coordinate the geological mapping of sensitive areas.
    - Support the implementation of a strong motion instrumentation program in Washington.
- Strengthening lifelines
    - Establish statewide policy goals for mitigation of seismic risk to lifelines.
    - Continue the funding for the current Washington State Department of Transportation (WSDOT) bridge retrofit program.
    - Identify critical lifeline routes that include state and local roads, bridges, transit routes, and port facilities.
    - Develop a work program for seismic vulnerability assessments of local bridges.
    - Require seismic vulnerability assessments and adoption of seismic mitigation standards for water and wastewater utilities.
    - Require post-earthquake response and recovery plans for water and wastewater utilities.
    - Provide a rigorous program of training in seismic safety for lifeline organizations.
    - Develop standardized safety guidelines for lifeline emergency plans.

In 1995, the Washington State Emergency Management Council (WSEMC) voted to establish the Seismic Safety Subcommittee. The tasks for this subcommittee were to provide policy recommendations, to serve as an advocate for seismic safety issues, and to provide an annual assessment of the implementation of seismic safety improvements to the council. The SSAC's 1991 report was to be used as the baseline to compare progress.

The Seismic Safety Subcommittee reviewed all major strategy recommendations, and noted in their *Earthquake Safety in Washington State* report (1998) that significant progress had been made in seismic safety in Washington since 1991.

The subcommittee's 1998 report identified three areas that warranted continued attention:

- Strengthen buildings
    - School buildings
    - Critical care facilities

- State facilities
- Strengthen lifelines
    - Power utilities
    - Gas utilities
    - Water utilities
- Strengthen transportation infrastructure
    - WSDOT bridge retrofit program
    - County and city bridge retrofit program

Their recommendations were to:

- Continue to follow the recommendations outlined in the 1991 plan;
- Accelerate the WSDOT retrofit program;
- Assess the vulnerability of transportation lifelines in counties and cities and establish a retrofit program; and,
- Provide further analysis and staffing by specialized workgroups to provide strategic planning for accomplishing recommended objectives from the 1991 policy plan.

B. Earthquakes in Washington State

This region has a long history of documented earthquakes. In January 1700, a great earthquake with an estimated magnitude of 9.0 affected the region. The December 14, 1872, North Cascades earthquake ranks as the most widely felt earthquake in the state. Other events include a magnitude 7.1 earthquake near Olympia in 1949 and a magnitude 6.5 earthquake near Seattle-Tacoma Airport in 1965. More than 20,000 earthquakes greater than magnitude 1.0 have been logged since 1970. This averages 656 events per year, or approximately two per day. Earthquakes of at least magnitude 2.0 to 3.0 have occurred in almost every county in the state.

Figure 1: Downtown Olympia, 1949

Figure 2: Downtown Olympia, 2001

Over the last 100 years, a large area of the state has experienced earthquake damage. The most damaging events have been the slab earthquakes that have hit the Puget Sound area since 1909. Most of the damage during the 1949 and 1965 earthquakes was concentrated in areas of filled ground along waterfronts, where there are many older masonry buildings. Damage occurred in many of the same locations during the 1949, 1965, and 2001 earthquakes. As with the 1965 event, no tsunami potential developed as a result of the Nisqually Earthquake. In 1949, a landslide-induced tsunami occurred in the Tacoma Narrows. Overall, the risk is greatest in western Washington, where historically the most earthquake damage has occurred and where much of the state's population lives. However, there have been significant earthquakes east of the Cascades as well.

Scientists have shown the following scenario regarding deep earthquakes in the Northwest. The moving slab of the Juan de Fuca plate originates some 250 miles out in the Pacific. Here, the sea floor splits apart and molten rock constantly wells up from the earth's viscous mantle beneath the crust, spreading both east and west as lava erupts and adds new material to the crust. This moving oceanic crust is about five miles thick where it starts diving beneath the continent along a well-mapped offshore structure called the Cascadia Subduction Zone.

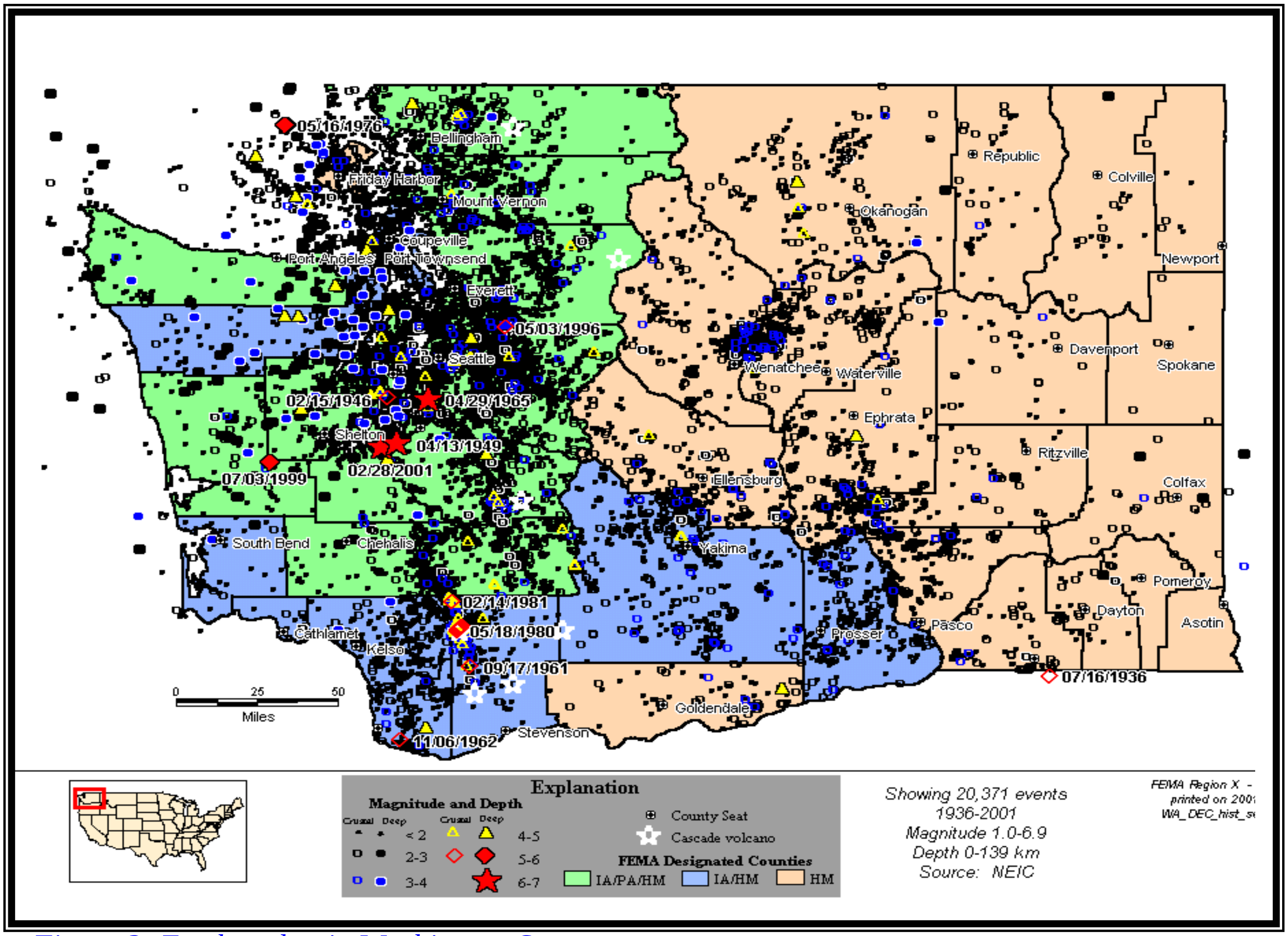

Figure 3: Earthquakes in Washington State

Pores in the oceanic lava are usually filled with water, but when the slab reaches the depth of 35 to 40 miles, where temperatures are well over 1,000 degrees Fahrenheit, the heat has driven most of the water out of the pores. At this point, the crustal slab becomes brittle, and stresses build up as the slab bends downward. Fault movements, resulting in an earthquake, release these stresses.

C. Recent Disasters in Washington State

Washington State was severely impacted by natural disasters from November 1995 to October 1998, resulting in eight federal disaster declarations. Damage occurred throughout the state from a complex series of winter storms with repeated cycles of freezing rain, snow, strong winds, and rapidly rising temperatures with warm rains. These weather conditions led to widespread power outages caused by fallen trees, multiple collapsed structures from the crushing weight of ice and snow, flooding from streams and rivers, blocked storm-drain systems, high groundwater tables with localized groundwater flooding, and the erosion of roads and hillsides with the subsequent loss of utilities and damage to homes.

Hundreds of landslides occurred throughout the state as a result of these winter storms, including some of the most dramatic slides in the state's history. Landslides destroyed many homes and threatened many more, primarily in and around the bluffs on Puget Sound. These slides destroyed infrastructure, undermined bridges, interrupted transportation facilities, knocked railroad cars into Puget Sound, and took four lives on Bainbridge Island.

Meteorological records show that the majority of slides occurred following heavy rain on top of wet snow. The excessive moisture from the winter storms saturated the ground, which already had excessive amounts of water from the previous two wet winters. The highest concentrations of landslides occurred in the West Seattle and Magnolia neighborhoods of Seattle; in Mukilteo and Edmonds in Snohomish County; and on Whidbey, Camano, and Bainbridge Islands. Typically, the slides were shallow, with most mobilizing into debris flows. Deep-seated slides and slumps also occurred, such as the slides in Magnolia and Woodway, which damaged and endangered structures.

In October 1998, the Aldercrest-Banyon subdivision in Kelso was declared a disaster site. This slow-moving, ongoing landslide impacted more than 130 homes. This event was the second largest landslide in a residential area in the history of the United States.

THE NISQUALLY EARTHQUAKE

The epicenter of this magnitude 6.8 earthquake was located approximately 50 miles south of Seattle and 11 miles northeast of Olympia, in an area locally known as the Nisqually Delta. Two minor aftershocks occurred within the same rupture area as the main shock. This event was a slab earthquake; its depth calculated at 36.7 miles below the earth's surface in the Juan de Fuca plate.

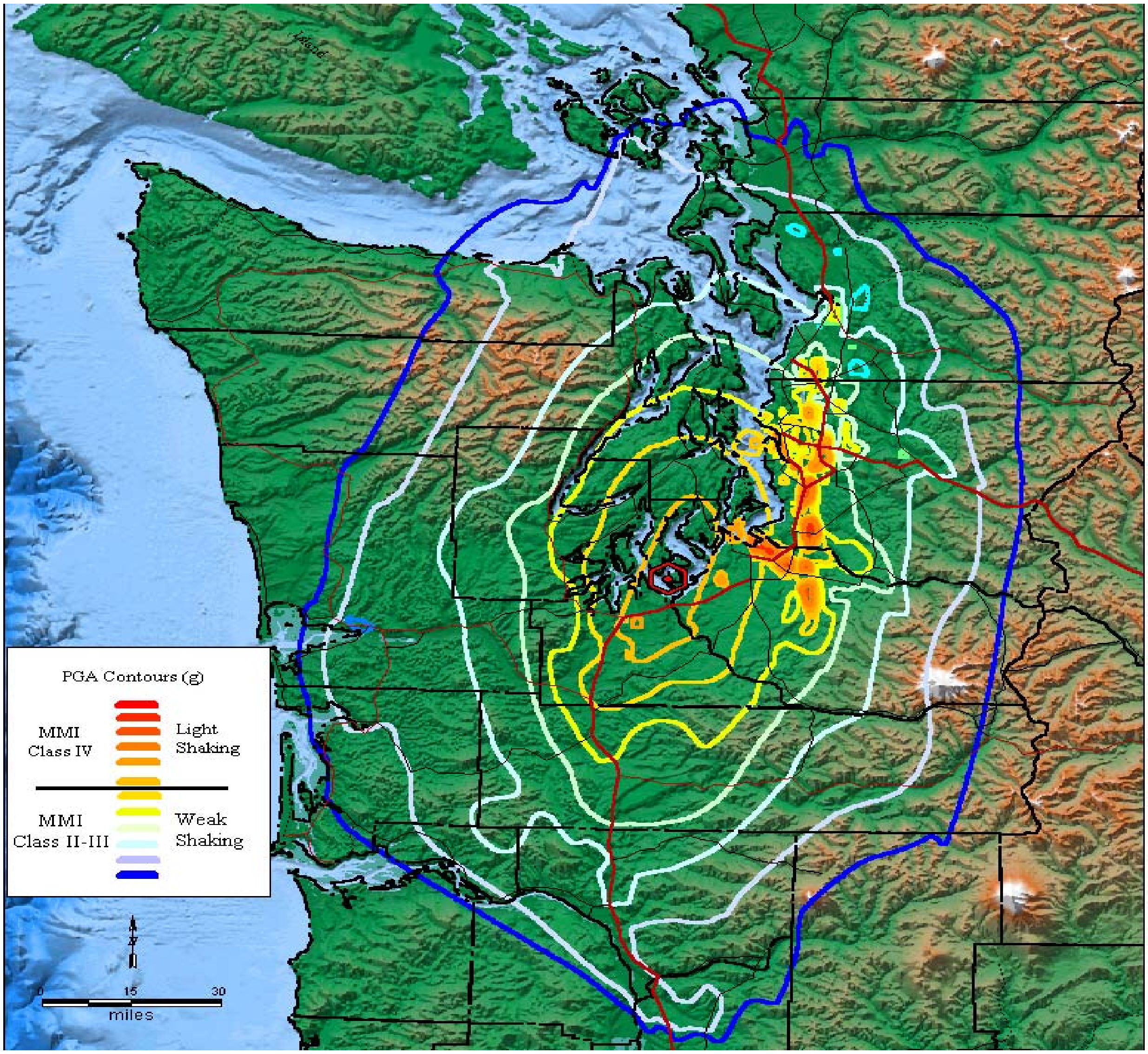

Figure 4: Computer model of ground shaking[1]

As is typical of an earthquake of this depth, the overall impact of the Nisqually Earthquake was less than that of a shallow earthquake of the same magnitude, but the earthquake was

[1]FEMA Region 10. This map is based on a computer model and incorporates no ground-based seismic information. The map is for general information only and should not be used for site-specific evaluations.

experienced over a greater area. The effects of the tremors could be felt as far as Vancouver, Canada, to the north; Portland, Oregon, to the south; and Salt Lake City, Utah, to the east.

Isolated pockets of soil liquefaction occurred in all of the counties surrounding the epicenter. The number of earthquake-related landslides was considered moderate, but some landslides did occur during the earthquake and in the first few weeks following the earthquake. Additional landslides will continue to be a heightened possibility throughout Puget Sound in periods of heavy rainfall.

A few unusual observations have been made regarding this earthquake. First, the ground shaking, captured for this event by strong-motion instruments, indicates that ground motions were apparently low for an earthquake of this type. This is probably due to the depth of the rupture.

Second, the area of most intense ground shaking was not centered around the epicenter, but along the heavily populated north-south I-5 corridor. This was probably due to the amplification of the earthquake waves on softer river valley sediments. In contrast, the area near the epicenter is underlain by firm glacial drift over hard bedrock, in which earthquake waves are not amplified.

And, finally, this event was completely unrelated to the known fault that runs across Seattle and Puget Sound in an east-west direction in the vicinity of I-90.

These observations and other data suggest that, although the effect of this earthquake was "moderate," it was a very important event to both scientists and planners. It has provided vital information about the area's seismology as well as implications for future earthquakes in this region. For planners in the disaster field, it was a wake-up call as well as an opportunity to carry out recovery and planning efforts so that we are even better prepared for future earthquakes.

DESCRIPTION OF DAMAGES

Immediately following the Nisqually Earthquake, the six counties most severely damaged were declared as federal disaster sites, making them eligible to receive federal funding for recovery through both public assistance and individual assistance grants. These counties were King, Kitsap, Lewis, Mason, Pierce, and Thurston. All counties in the State of Washington were automatically made eligible for hazard mitigation assistance with the disaster declaration.

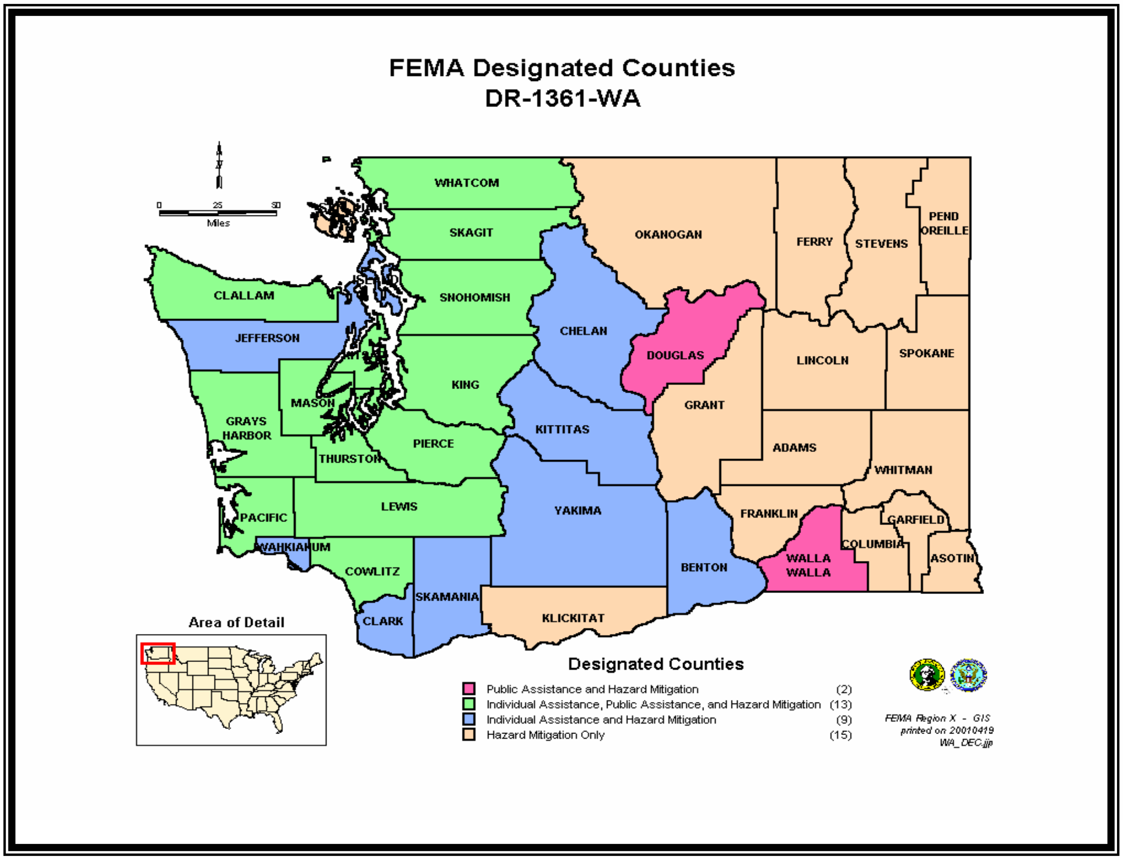

Figure 5: FEMA designated counties DR-1361-WA

At this writing, a total of thirteen counties have been declared for both public assistance and individual assistance. These include Clallam, Cowlitz, Grays Harbor, King, Kitsap, Lewis, Mason, Pacific, Pierce, Skagit, Snohomish, Thurston, and Whatcom. Nine counties – Benton, Chelan, Clark, Island, Jefferson, Kittitas, Skamania, Wahkiakum, and Yakima – have been declared for Individual Assistance only; and two – Douglas and Walla Walla – have been declared for public assistance only.

Indian tribal governments eligible for public assistance and individual assistance funding include the Confederated Tribes of the Chehalis Reservation, Jamestown S'Kallam Tribe, Lower Elwha, Lummi Nation, Makah Tribe, Muckleshoot Tribe, Nisqually Tribe, Nooksack Tribe, Port Gamble Indian Community, Puyallup Tribe, Quileute Tribe, Quinault Tribe, Samish Nation, Sauk-Suiattle Tribe, Shoalwater Bay Tribe, Skokomish Tribe, Snoqualmie Tribe, Squaxin Island Tribe, Stillaguamish Tribe, Suquamish Tribe, Swinomish Tribe, The Tulalip Tribe, and the

Upper Skagit Tribe. The Hoh Tribe and the Yakama Nation are eligible for Individual Assistance only. All tribal governments in the state are eligible for hazard mitigation assistance.

The Nisqually Earthquake resulted in 400 injuries (a dozen of them serious) and one confirmed death (a trauma-induced heart attack).

Lifeline systems, with the exception of airports, performed remarkably well during the event, and the impact of lifeline damage was in most cases minimal. Lifelines include water, wastewater, electrical power, communications, natural gas and liquid fuels, and transportation systems. Minor structural damages were reported to water utilities. Only one gas line leak was reported. This fire/explosion occurred when two maintenance workers were resetting an earthquake valve at a correctional facility near Olympia. Seattle City Light reported 17,000 customer power outages; Puget Sound Energy reported 200,000, but power was restored to most within a day. Landline and wireless communication systems were extremely overloaded immediately following the earthquake, and the King County 800 MHz radio system (intended to provide reliable communications during disaster events) was only partially functional the day of the earthquake.

Several of the government buildings in Olympia, including the capitol, were significantly damaged. The 74 year-old capitol dome sustained a deep crack in its limestone exterior and damage to supporting columns. There were a number of other non-structural damage areas throughout the building. Other state agency buildings were closed for inspection and repair.

Figure 6: Damage repair to the capitol

Transportation systems suffered more extensive damage. There was serious damage to the region's largest airports. Seattle-Tacoma International Airport was immediately closed because the control tower was completely disabled. The tower suffered both structural and non-structural damage. A temporary backup control tower allowed reopening after several hours to limited traffic. The King County Airport (Boeing Field) suffered serious cracking and gaps on the runway due to soil liquefaction and lateral spreading. The main runway was reopened for business after a week.

While the area's overall road network remained functional, numerous parts of highways, roads, and bridges were damaged. Several state routes and local roadways were closed due to slumping and pavement fractures. Two bridges were closed due to significant damage – the Magnolia Bridge in Seattle and the 4th Avenue Bridge in Olympia. Although damage to most other bridges was minor, additional earthquake damage has been discovered on Highway 99, the Alaskan Way Viaduct, a major arterial in Seattle.

There was minor damage to dock facilities in both Tacoma and Seattle. Fortunately, this damage was not extensive enough to interrupt commercial port services, as the ports of Puget Sound are critical to the economic viability of the area.

The state's dams fared quite well during the earthquake. Of the 290 dams inspected by state engineers, only five dams were found to have earthquake-related damage. These dams were the Eden Creek Dam on McNeil Island in Pierce County, Cascades Dam at Lake Young and the Snoqualmie Mill Pond Dam in King County, the Chamber Creek Reservoir Dam in Pierce County, and the McAllister Springs Reservoir Dam in Thurston County. This minor amount of damage is due to the relatively low ground accelerations generated by the earthquake, coupled with the fact that most well constructed earthfill dams have minimal problems with earthquake shaking. The five dams that were damaged were all poorly constructed dams on weak foundations, and were already recognized as being susceptible to damage from earthquakes. No earthquake related damage was found at the other dams in the state that are controlled or regulated by the Federal Energy Regulatory Commission (FERC), the Bureau of Reclamation, or the U.S. Army Corps of Engineers.

Building damage varied widely throughout the region. Seattle's historic Pioneer Square District and downtown Olympia were hit hard. Unreinforced brick masonry buildings with unbraced parapets and without wall anchors were particularly vulnerable, resulting in several collapses. Throughout the impacted area, over a thousand buildings were either red-tagged or yellow-tagged for inspection. Many of these businesses were declared unsafe and were closed for weeks.

Other businesses, most with non-structural, cosmetic damage, closed temporarily for detailed inspections. While severe structural damage to businesses was relatively limited, non-structural damage, and the associated business disruption, caused significant economic loss.

Figure 7: Viewing the damage after the earthquake

Numerous facilities experienced non-structural damage, such as ceiling failures, shifting of equipment, fallen furniture/shelving, desktop computer damage, and fallen light fixtures.

Damage to residences came in a variety of forms, from severe mudslide destruction of entire houses to breakage of replaceable personal property. The most common damage was to chimneys. FEMA records indicate that one-third of the 30,000 homes inspected by FEMA sustained chimney damage. Those areas hardest hit include road and foundation failures in a Nisqually area mobile home park and the Sunset Lake Mobile Home Park in Tumwater; landslides at Salmon Beach near Port Defiance in Tacoma; and mudslides and flooding in Maplewood near Renton.

Figure 8: Road damage from the Nisqually Earthquake

Initial cost estimates for all declared counties requesting public assistance (PA) and individual assistance (IA) have been compiled and are presented on page 16. These costs do not include the Hazard Mitigation Grant Program (HMGP), which provides assistance to state, tribal, and local governments for long-term actions that reduce risk to life and property from hazards such as the Nisqually Earthquake.

Figure 9: Salmon Beach, Tacoma, 1949

Figure 10: Salmon Beach, Tacoma, 2001

Initial Damage Estimates for Public Assistance and Approved Individual Assistance Grants (as of June 7, 2001)

County	Public Assistance Estimates	Individual Assistance Approvals	Totals
Benton	ND	$62,283	$62,283
Chelan	ND	$36,601	$36,601
Clallam	$298,500	$105,757	$404,257
Clark	ND	$180,150	$180,150
Cowlitz	$268,200	$221,616	$489,816
Douglas	$25,500	ND	$25,500
Grays Harbor	$618,450	$2,679,997	$3,298,447
Island	ND	$117,450	$117,450
Jefferson	ND	$100,124	$100,124
King	$109,349,506	$16,480,730	$125,831,236
Kitsap	$2,918,930	$2,851,556	5,770,486
Kittitas	ND	$76,260	$76,260
Lewis	$3,447,200	$1,509,922	$4,957,122
Mason	$1,113,295	$978,979	$2,092,274
Pacific	$65,000	$355,484	$420,484
Pierce	$28,064,596	$8,928,288	$36,992,884
Skagit	$999,250	$409,592	$1,408,842
Skamania	ND	$8,859	$8,859
Snohomish	$1,837,680	$983,751	$2,821,431
Thurston	$55,075,553	$4,940,763	$60,016,316
Wahkiakum	ND	$51,614	$51,614
Walla Walla	$153,000	ND	$153,000
Whatcom	$399,945	$590,195	$990,140
Yakima	ND	$394,063	$394,063
Total	**$204,634,605**	**$42,064,034**	**$246,698,639**

ND = Not Declared for this category

EARLY IMPLEMENTATION STRATEGY PROGRESS REPORT

Significant progress has been made on each of the strategies formulated for the Early Implementation Strategy Report of March 15, 2001. Below are the original strategies with progress notes as of the completion of this HMST Report.

A. Develop Informational and Technical Processes for Assessing Damage

Mitigation specialists were assigned to each of the Public Assistance Teams to collect detailed damage information. The specialists were provided two worksheets that allowed documentation of the types and character of damage to public and residential facilities. In addition, selected mitigation specialists made field trips to document unique damages, such as those associated with landslides. All of the above information was summarized and entered into a database to facilitate its use. Geographic Information System (GIS) maps that display the damage were produced.

A Technical Coordination Center was created to provide consultation on technical issues unique to this disaster. Issues addressed by the Center included:

- Development of a policy for evaluating landslides as related to the repair of damaged facilities;
- Inspection of all dams for potential damage;
- Inspection of geologic structures, including Mount Rainier, Mount Baker, and the landslide dams at Mount St. Helens, for potential damage;
- Inspection of levees for potential damage;
- Development of a policy related to proper application of codes and standards;
- Development of a policy for evaluating potential damage to welded steel moments; and
- Development of a policy for inspection of structural damage to buildings.

Additional priorities will be to physically collect and archive data based on remaining activities.

B. Establish HMGP Priorities for Funding Consideration

FEMA has approved the Nisqually Earthquake HMGP Administrative Plan for the Washington State Emergency Management Division (WSEMD). Preliminary identification of priorities in the Early Implementation Strategy will be further refined by input from the HMST meetings.

C. Conduct Joint HMGP Application & Review by FEMA Region 10 Staff

Training of new WSEMD staff is scheduled for July 2001. FEMA and WSEMD will continue working in close consultation to develop viable HMGP projects for funding.

D. Incorporate the Region's Existing Earthquake Consortia into the State's Mitigation Strategy

FEMA, WSEMD, the University of Washington, and United States Geological Survey (USGS) have partnered to form the Nisqually Earthquake Clearinghouse, which will serve as a hub for post-event data collection and research. The Cascadia Region Earthquake Workgroup (CREW) has also been commissioned to complete a study on the earthquake's impact on businesses. The results of both of these efforts will aid the state in updating its Hazard Mitigation Strategy Plan.

The Nisqually Earthquake Clearinghouse became operational on March 29, 2001, at the University of Washington. Several objectives have been accomplished to date:

- Established GIS processing capability.
- Established on-line capability for receiving and processing digital data.
- Conducted an extensive survey of data services and users to develop an inventory of data sets.
- Established a web site to display transfer data.

E. Identify Potential Projects for Flood Hazard Mapping Related to the Earthquake

FEMA plans to study the flood potential of two areas significantly impacted by the Nisqually Earthquake. These two areas are the Cedar River in King County and the Deschutes River/Capitol Lake area in Olympia.

F. Encourage Long-term Planning

WSEMD will take the recommendations from the HMST as a baseline for updating its Hazard Mitigation Strategy. In addition, other state agencies will contribute to the formulation of damage prevention strategies and policies as appropriate.

G. Initiate an Aggressive Community Education Program

FEMA's Community Education Branch worked with the state to deliver the message *Rebuilding for the Future: Safer, Stronger, Survivable.* This coordinated effort addressed a wide range of audiences with a tailored message for each marketing opportunity and emphasized the sustainability of efforts. The team:

- Built three sets of retrofits models that included a structural cut-away of a home, a non-structural cabinet model, and a chimney model. These models were used as part of the "Road Show" that provided mitigation presentations to a wide variety of target audiences, including technical colleges, federal agencies, and hardware stores. Presentations ranged from 30 minutes to two hours in length and provided mitigation retrofit, preparedness, and sustainability information.
- Supported current education efforts by distributing 2,950 education packages to elementary, middle, and high schools. Some of the items included in each education package were the mitigation and preparedness school curriculum, the *Earthquake… Drop, Cover and Hold* training videotape, and earthquake preparedness storybooks.
- Provided mitigation technical assistance to over 2,500 individuals at Disaster Recovery Centers and through the mitigation assistance telephone line.
- Provided each individual that registered through the National Processing Service Center (NPSC) with a household retrofitting information package with structural and non-structural mitigation measures.
- Set up mitigation kiosks and booths at seven state events and fairs.

- Produced chimney inspection and retrofit and business earthquake preparedness posters.
- Participated in six radio and two television interviews and 28 press releases.

H. Document and Market Mitigation Successes

Mitigation measures that were taken prior to the Nisqually Earthquake have been reviewed and several selected to be used as success stories to market the concept of mitigation. These stories are detailed in the report entitled *Rebuilding for the Future: Stronger, Safer, Survivable - Mitigation Successes Following the Nisqually Earthquake.* The successes that were selected included structural and non-structural seismic strengthening/retrofit of residential buildings, public structures, infrastructure, schools, health care facilities, and a childcare center. Also featured are programs such as community home retrofit training and school district non-structural retrofits. Several programs have used a multi-hazard approach which incorporated mitigation for both flood and earthquake hazards.

Funding sources for these mitigation successes are varied. Projects were funded through such programs as the HMGP, FEMA's Project Impact, community tax levy, corporation capital improvement project budgets, and private sources.

One of the mitigation success stories, the City of Mercer Island Reservoir, was included in a NEHRP report to Congress. This story, along with several others, is included in the next section of this report.

HAZARD MITIGATION SUCCESS STORIES

Washington State has been very proactive regarding earthquake hazards. The Emergency Management Division, under the auspices of the Washington Military Department, has developed partnerships and programs with many private businesses and local agencies to enhance emergency preparedness and mitigation throughout the state. Additionally, the City of Seattle was selected as one of the original communities to participate in FEMA's Project Impact initiative. Results of these efforts were evident following the Nisqually Earthquake. Five of the stories that demonstrated successful preparedness are included here.

A. Little Church on The Prairie Learning Center

Partners for Loss Prevention, an Oregon non-profit organization, and Project Impact of King & Pierce Counties organized the non-structural retrofit of the Little Church on the Prairie Learning Center in Lakewood, Washington, to demonstrate how child-care centers can be made safer.

Figure 11: Checking crib anchor strapping

Puget Sound Energy and Key Bank of Lakewood supplied financial support, and a group of volunteers gathered together to do the work. The team secured bookcases and cabinets and anchored cribs, refrigerators, and other tall objects. Members of the Pierce County Fire Marshall's Office installed protective sheathing on fluorescent light tubes.

When the Nisqually Earthquake hit, the children and staff of the Little Church on the Prairie Learning Center were protected from falling objects because the Center had completed this non-structural mitigation of the facility. Though the center suffered some structural damage, there was no damage inside. And, most importantly, there were no injuries.

B. City of Mercer Island Reservoir and Pump Station

Mercer Island in Lake Washington is a busy community located east of Seattle, accessible only by the I-90 floating bridge. The residents are totally dependent on two aboveground steel water reservoirs, four million gallon capacity each, for their main source of water. This water supply is also essential for fire fighting.

Figure 12: Flexible pipes at the Mercer Island pump station

The City of Mercer Island applied for, and was granted, funding through the HMGP for seismic retrofit of the reservoirs and pump station. The pump station, which pressurizes all the water through a system of pipes, and then delivers it to the upper end of the island, was completely retrofitted. Because of its critical function, restraints were installed to the emergency generator and other large pieces of equipment and control cabinets were bracketed to the walls. Sections of rigid pipes were replaced with flexible connections. These specially designed connections will move in the direction of earthquake activity while maintaining their integrity.

Mercer Island sustained a great deal of shaking during the earthquake. Those located close to the reservoirs during the earthquake state that the water in the reservoirs "sloshed for an hour." The reservoirs rode through the earthquake with no damage and performed just the way the retrofit was designed. Subsequent engineering inspection has determined that there is no threat of collapse of any of the retrofitted structures.

One of the primary power poles close to the reservoir went down, causing a local power outage. Power was out for over six hours, but an automatic generator came online and maintained the function of the pumps without any disruption of service. This timely mitigation project eliminated danger to Mercer Island homes and structures, as well as protecting the water supply.

Figure 13: Equipment tied down

C. Private Home: Seismic Construction

The process of building their dream home began for Dick and Carol Heavener of Poulsbo, Washington, with the purchase of house plans. Carol and Dick figured it would be at least an 80% savings to add seismic strengthening measures into their design plans from the beginning as compared to doing a retrofit after construction. A new set of plans, which included the seismic measures, was developed.

Because of the 45-degree angle on the front face of the house, special one-piece ties were designed with brace supports for the columns in all of the beams. Special connectors were specifically designed with splits and were made stronger to accommodate angles in the house. This technique was repeated throughout each level with the use of anchor plates and strap ties strategically installed for added reinforcement.

Figures 14-16: Details of the Heavener home

The Poulsbo area received widespread damage during the Nisqually Earthquake. But at the Heavener's house, no glass jars or dishes on the shelves were damaged. Many chimneys in the area were damaged, but the Heavener's did not move. The Heavener's retrofit measures were tested and passed without a hint of damage.

Market value of this home, when completed, is estimated at $400,000. The value of their security from knowing they have a seismically sound house is priceless.

D. Rainier Manor Mobile Home Park Retrofit

Rainier Manor Mobile Home Park sits in a bowl on the banks of the Puyallup River in King County, Washington. In 1995, excessive spring rains and an early snowmelt in the mountains caused a nearby levy to overflow. Over half of the 75 homes in the park flooded, and most of the mobile homes were destroyed or severely damaged. This prompted a visit by a National Flood Insurance Program (NFIP) agent.

The NFIP, along with the Small Business Administration (SBA), set up a Reconstruction Information Center in the mobile home park. Its purpose was to educate residents and convince them to not only elevate for flood, but to do a seismic retrofit for earthquake at the same time. As a result, new seismic bracing standards were incorporated with the best methods for securing mobile homes to their foundations.

In 2001, not one Rainier Manor home was damaged by the Nisqually Earthquake. The success of this story lies not only in the fact that no home was damaged from the earthquake, but that six years earlier agents from the NFIP and SBA had turned an otherwise disastrous situation into a positive result. Their patience, guidance, and assistance created a safe environment for every resident in the Rainier Manor Mobile Home Park.

Figures 17 & 18: New mobile homes with multi-hazard protection: elevated against flood and seismically bolted/strengthened against earthquakes

E. Seattle School District: Non-structural Retrofit Program

The Seattle School District has been aggressively pursuing a safer environment for their students and faculty for many years. In the 1949 and 1965 earthquakes, the school district experienced substantial damage to both public and private schools. This heightened awareness of the vulnerability of state schools, particularly those older buildings constructed of unreinforced masonry. Earthquake safety for schools became an ongoing objective.

History of Earthquake Losses to Washington State Schools

YEAR	PROPERTY LOSSES	CASUALTIES	COSTS
April 1949	• 30 schools closed • 10 condemned	Two students killed by falling bricks	Total loss: $60 million • repair and replacement costs $28 million (1998 dollars)
April 1965	• 8 schools closed • 2 severely damaged	None reported	Total loss in excess of $60 million (1998 dollars)
February 2001	• limited school closure	None	*(not available at the time of this report)*

Source: Safer Schools Earthquake Hazards Non-structural, Lessons Learned Seattle School District, November 2000, Second Edition, Noson & Perbix

Currently, the Seattle School District is implementing a program of non-structural retrofit for all of their schools. Non-structural measures taken to date include: display case strapping; securing of book cases, audio/visual equipment, and library shelves; securing of desk top and counter top equipment, such as computers, aquariums and microwaves; securing of ceiling light fixtures, and wall mounted speakers and sound systems; and securing heavy floor-mounted equipment, such as drill presses, vending machines, and large shelving. Safety film has been installed on all interior glass.

When the earthquake struck, all of the schools in the Seattle School District were shaken. There was enough ground motion to trip gas shut off valves, but structural damage was minimal compared to losses suffered in the past two significant earthquakes.

Several teachers sent memos to Theresa Salmon, Special Projects Administrator, thanking her for the measures that were implemented in their schools. A school nurse wrote: “Just wanted to let you know the good news on how well Mercer (the building) did during the earthquake—and a big thanks for the retrofitting. We did not even have a single light cover come down, a computer fall over, (or) a book come off a shelf. Now, how do we get more straps to do the new things we have installed since retrofitting was done here? Think you have made believers out of us!”

Figure 19: Shelves attached to walls in Seattle School District

MITIGATION RECOMMENDATIONS

A. Summary of HMST Meetings

During the last week of April 2001, three HMST meetings were held in Olympia, Everett, and Yakima. The purpose of these meetings was to draw together representatives from federal, state, tribal, and local agencies to share information on the impact of the Nisqually Earthquake. Participants were asked to engage in discussions that led to developing a series of recommendations for inclusion in the Washington State *Hazard Mitigation Strategy* and in identifying potential HMGP projects. A list of participants can be found in the Appendices.

The participants identified issues and recommendations for actions in the following areas:

- Building codes
- Earthquake disaster information
- Earthquake preparedness
- Critical lifelines
- Critical facilities
- Seismic safety commission
- Earthquake loss estimates
- Incentives for seismic upgrades
- Long-term planning

B. Recommendations

The following recommendations evolved from these meetings. Together, they provide a framework designed to achieve agency coordination and cooperation. The success of these actions will require a cooperative effort among federal, state, tribal, and local agencies as well as other organizations. Agencies other than those included in this report may be involved in implementing the recommendations.

Building Codes

Background:

The built environment suffered an estimated $350 million in damages during the Nisqually Earthquake. With the region prone to large earthquakes from the Cascadia Subduction Zone and the many active crustal faults in the state, the extreme ground shaking and severe intensity levels from this type of quake makes our built environment highly vulnerable. With many local codes and response plans based on slab earthquakes such as the Nisqually quake, new building codes with more stringent building standards are needed to offset the potential devastation that would be caused by a large crustal fault earthquake.

Washington State adopts, by reference in statute, the Uniform Building Code (UBC). The State Building Code Council (SBCC) updates the editions. The SBCC is currently reviewing the complete International Building Code (IBC), including the structural chapters 16-23. However, they are not authorized to adopt the IBC until the State Legislature changes the enabling law. The IBC uses site-specific designations for seismic design factors, a change from the numeric seismic zones in the UBC, resulting in a more accurate design guide for earthquake resistant construction. (Note: this may mean a less stringent code in some cases.)

Recommendations:

- Adopt the International Building Code.
- Re-evaluate statewide seismic designations as they pertain to building codes.
- Coordinate the mitigation efforts on historic structures with the State Historic Preservation Office. This includes codified standards and guidelines for retrofits, and the adoption and enforcement of a seismic safety ordinance for historic structures.
- Develop a program for seismic retrofitting of federal, state, and local government public buildings that cannot shut down, even briefly, during a disaster.

Recommended Agencies:

Washington State Historic Preservation Office
Washington State Office of Community Development
Seismic Safety Advisory Committee
State Building Code Council

Earthquake Disaster Information

Background:

Post-earthquake technical clearinghouses, such as the Nisqually Earthquake Clearinghouse, have become important components of emergency response, recovery, and mitigation. Seismologists deploy instruments that measure aftershocks and investigate the mechanics of earthquakes. Geologists and geotechnical engineers document ground failures, including fault displacements, fissures, landslides, rock falls, and liquefaction. Geodesists investigate ground deformation and related strain. Structural engineers evaluate the effects of the earthquake on various types of buildings, bridges, dams, utilities, and other structures. Social scientists study direct impacts to people and businesses.

Data collected in the days immediately following a major earthquake can be critical during emergency response and recovery. Some data are perishable and must be collected as soon as possible. These data will help us to be better prepared for future earthquakes as they assist in calibrating loss-estimation models, such as FEMA's Hazards United States (HAZUS). In addition, they also establish a mechanism for relaying information from scientific and engineering investigations to emergency managers.

The earthquake demonstrated that there is a need for accurate real-time earthquake data. Many local emergency managers found themselves struggling to get accurate information following the quake. With much of the media focusing on the Seattle area, many on the eastside of the state were left without pertinent information for their regions and, as such, it was treated as a non-event by many eastside television and radio stations.

Recommendations:

- Provide a basis and catalyst for the Nisqually Earthquake Clearinghouse to develop into a multi-hazard center that can gear up to serve the disaster mission in the same way during future disasters. In between disasters, the center would serve as a public awareness, preparedness, and mitigation source.

- Establish resources such as an Internet website, local cable access, or the National Oceanic and Atmospheric Administration (NOAA) weather radio system that would be available after a disaster to emergency managers, other public officials, and the public-at-large for consistent and correct situational updates on a statewide basis.

Recommended Agencies:

Federal Emergency Management Agency
National Oceanic and Atmospheric Administration
Washington State Department of Natural Resources
Washington State Emergency Management Division
University of Washington

Earthquake Preparedness

Background:

Many of the successes seen after the Nisqually Earthquake were the result of programs designed to incorporate general safety issues as well as earthquake hazard reduction. Teachers and students carried out drills on how to respond during an earthquake. Many businesses, state, tribal, and local agencies, school districts, and individual citizens did their part in reducing earthquake damage by completing structural and non-structural seismic retrofit projects.

However, the Nisqually event was the wake-up call needed to intensify public education, training, and awareness of earthquake preparedness. Television broadcasts showed adults reacting in very dangerous fashion during and following the quake. Several of the state's 911 emergency systems were overloaded with non-emergency phone calls. Many businesses released their employees, producing a mass exodus and jamming freeways before transportation lifelines could be evaluated for damage.

Recommendations:

- Develop a version of the "Drop, Cover, and Hold" campaign designed for adults.
- Develop school emergency plans and procedures messages for distribution to parents and the media before a disaster emergency strikes.
- Create a public service campaign advising Washington State citizens about the appropriate use of 911 lines during a disaster emergency.
- Market the success of non-structural mitigation in this event, emphasizing the ease and relatively low cost of non-structural mitigation.
- Provide funding for non-structural seismic mitigation measures in facilities that serve large numbers of vulnerable populations (i.e., children, elderly, low income).
- Study the commission of the creation of a monument to the Nisqually Earthquake.

Recommended Agencies:

Washington State Emergency Management Division
Office of the Superintendent of Public Information
Washington Utilities and Transportation Commission
Local school districts

Critical Lifelines

Background

A lifeline is a linear system necessary for human life and urban function. Lifelines convey food, water, fuel, and other materials needed for human existence. These systems include transportation routes, such as highways and bridges; energy systems, such as electricity, transmission lines, and gas pipelines; emergency service facilities, such as hospitals and fire stations; telecommunication systems; and water supply systems, such as treatment plants, pipelines, and aqueducts.

An earthquake is the natural disaster most likely to lead to major disruption of lifelines. Transportation is essential to Washington's vitality. The risk to local bridges, marine or port facilities, highways, transit systems, airports, and rail facilities from earthquakes must be determined so that priority can be given to mitigating critical routes, staging areas, and facilities. Communication systems often lack interagency operability and can prevent essential communication during and immediately following a disaster.

The interactive nature of lifelines compounds the problems of lifeline disruption. For example, water supplies can be dependent upon electricity. In many cases, bridges carry telecommunication landlines and power cables. Thus, a bridge failure can result in a power failure cutting off an area's water supply. State efforts to improve the seismic safety of lifelines must include: transportation routes and facilities; water, power, and wastewater systems; pipelines; and telecommunications.

Recommendations

Assess the disaster survivability of lifeline transportation routes, to include state and local roads, bridges, transit routes, railroad, and port facilities. Determine appropriate retrofits and prioritize emergency routes.

Create a website displaying statewide highway and lifeline maps, including critical facilities, critical routes, and vulnerable bridges. Serve the public by encouraging traffic direction along identified evacuation routes. Serve inter-jurisdictional planning through route identification and drawing of contingency routes.

Enhance and accelerate the Washington State Department of Transportation (WSDOT) Bridge Retrofit Program to include seismic risk to eastern Washington bridges.

Critical Lifelines (Continued)

Require vulnerability assessments and adoption of mitigation standards for water and wastewater utilities.

Develop mutual aid agreements between counties on a regional level to include lifeline issues.

Recommended Agencies:

Washington State Emergency Management Division
Washington State Department of Natural Resources
Washington State Department of Transportation
Washington State Utilities and Transportation Commission
Washington State Department of Ecology
Local emergency management departments
Association of Emergency Planners
Association of Washington Cities
County Road Administration Board
Public and private utilities
United States Geological Survey
University of Washington

Critical Facilities

Background:

Critical facility identification and protection is lacking in many communities, as is the need to identify and protect essential lifelines. Among the public support facilities to consider for seismic risk reduction are police and fire stations, schools, public buildings, water and wastewater treatment plants, and hospitals and other health care facilities. Utility suppliers should be considered as well.

Recommendations:

- Identify, inventory, and perform risk assessments of critical facilities to facilitate prioritizing structural and non-structural retrofits based on vulnerability.
- Accelerate tsunami inundation mapping of western Washington to include landslide susceptibility.
- Continue mapping zones of liquefaction and amplification and distribute the data to local officials to enhance incorporation of mitigation into land use planning.
- Review hazard zones in Washington (i.e. tsunami inundation, potential lahar pathways, flood plains) and develop draft legislation to restrict building of critical facilities in these areas.

Recommended Agencies:

Washington State Emergency Management Division
Washington State Department of Natural Resources
Association of Washington Cities
Washington Department of Social and Health Services
Washington State Office of Community Development, GMA
Office of Superintendent of Public Instruction
Washington Association of Emergency Planners
Washington State Utilities and Transportation Commission
Local emergency management departments

Seismic Safety Commission

Background:

In November 1995, The Washington State Emergency Management Council (WSEMC) established the Seismic Safety Subcommittee to serve as the focus group for activities related to seismic safety. The group was organized to:

- Coordinate the development of a statewide strategy for educating, mitigating, planning, and responding to the threat of seismic events using the SSAC's *A Policy Plan for Improving Earthquake Safety in Washington – Fulfilling Our Responsibility* (1991) as a baseline.
- Ensure an effective and coordinated mechanism exists to assess and disseminate risk and threat information.
- Identify resource opportunities and recommend appropriate lead agencies or other lead entities for specific seismic issues.
- Provide a forum for general coordination and the exchange of information among federal, state, tribal, local, and private entities.
- Recommend policy changes to improve and enhance statewide seismic safety.
- Provide an annual assessment of statewide implementation of seismic safety improvements to WSEMC.

The Seismic Safety Subcommittee has been restructured to meet the goals and objectives of the WSEMC and will be updating statewide seismic safety priorities for inclusion into the Washington State *Hazard Mitigation Strategy*.

Recommendation:

Review various options to formalize a permanent Seismic Safety Commission that is fully funded and accountable to the Governor and State Legislature.

Recommended Agencies:
Washington State Emergency Management Division
Seismic Safety Subcommittee

Earthquake Loss Estimates

Background:

The FEMA HAZUS earthquake loss estimates are forecasts of damage, and human and economic impacts that may result from future earthquakes. They are not precise predictions, but rather estimates based on current scientific and engineering knowledge. WSEMD and FEMA Region 10 have partnered to develop a HAZUS Training Program that is made available to the public and private sectors in Washington. HAZUS was used extensively during the response phase of the Nisqually Earthquake.

Recommendation:

Continue the validation and refinement of HAZUS with data from this event.

Recommended Agencies:
Federal Emergency Management Agency
Washington State Emergency Management Division

Incentives for Seismic Upgrades

Background:

There are no governmental financial programs in Washington State to encourage property owners to conduct seismic safety upgrades of their facilities. A poll taken of insurance providers indicated that many companies providing earthquake coverage are restricting sales to those dwellings that have already been retrofitted. The average deductible is 10 percent of the dwelling's value.

Recommendations:

- Resolve the discrepancy between federal requirements that public facilities carry earthquake insurance and the reticence of insurance companies to underwrite policies on older unreinforced masonry structures.

- Provide incentives to policyholders to undertake structural and non-structural seismic retrofits. The Washington State Insurance Commissioner should work with insurance companies to find these incentives.

- Encourage lending institutions to provide low-interest mitigation loans for businesses and homeowners.

Recommended Agencies:

Washington State Emergency Management Division
Washington State Office of the Insurance Commissioner
Small Business Administration
Financial institutions

Long-Term Planning

<u>Background:</u>

All local governments are required to update their Critical Area Ordinances (CAO) by September 2002 (this deadline could change through legislative action this 2001 session). Over 200 local governments are also required to review and update their comprehensive plans by September 2002. This presents an ideal opportunity to build disaster resistance into local land use plans.

<u>Recommendations:</u>

Incorporate hazard mitigation into the traditional planning process, using the Growth Management Act as a springboard.

Provide funding to local governments to encourage regional planning approaches and the formation of multi-jurisdictional partnerships.

<u>Recommended Agencies:</u>

Washington State Emergency Management Division
Washington State Department of Natural Resources
Washington State Office of Community Development
Washington Association of Cities
Washington Association of Counties
Regional planning associations

APPENDICES

I. Earthquake Glossary

This glossary includes words commonly used to describe the nature of earthquakes, how they occur, and their effects, as well as a discussion of the instruments used to record earthquake motion.

Accelerograph: A seismograph whose output is proportional to ground acceleration (in comparison to the usual seismograph whose output is proportional to ground velocity). Accelerographs are typically used as instruments designed to record very strong ground motion useful in engineering design; seismographs commonly record off scale in these circumstances. Normally, strong motion instruments do not record unless triggered by strong ground motion.

Aftershock: One of many earthquakes that often occur during the days to months after some larger earthquake (mainshock) has occurred. Aftershocks occur in the same general region as the mainshock and are believed to be the result of minor readjustments of stress at places in the fault zone.

Amplitude: The amplitude of a seismic wave is the amount the ground moves as the wave passes by. (As an illustration, the amplitude of an ocean wave is one-half the distance between the peak and trough of the wave. The amplitude of a seismic wave can be measured from the signal recorded on a seismogram.)

Aseismic creep: Movement along a fracture in the Earth that occurs without causing earthquakes. This movement is so slow that it is not recorded by ordinary seismographs.

Collision: A term sometimes applied to the convergence of two plates in which neither plate subducts. Instead, the edges of the plates crumple and are severely deformed.

Convection: The motion of a liquid driven by gravity and temperature differences in the material. In the Earth, where pressure and temperature are high, rocks can act like viscous fluids on a time scale of millions of years. Thus, scientists believe that convection is an important process in the rocks that make up the Earth.

Convergent boundary: The boundary between two plates that approach one another. The convergence may result in subduction if one plate yields by diving deep into the Earth, obduction if one plate is thrust over the other, or collision if the plates simply ram into each other and are deformed.

Core: The Earth's central region, believed to be composed mostly of iron. The core has a radius of 3,477 kilometers and is surrounded by the Earth's mantle. At the center of the molten outer core is a solid inner core with a radius of 1,213 kilometers.

Earthquake: The release of stored elastic energy caused by sudden fracture and movement of rocks inside the Earth. Part of the energy released produces seismic waves, like P, S, and surface waves that travel outward in all directions from the point of initial rupture. These waves shake the ground as they pass by. An earthquake is felt if the shaking is strong enough to cause ground accelerations exceeding approximately 1.0 centimeter/second^2.

Epicenter: The location on the surface of the Earth directly above the focus, or place where an earthquake originates. An earthquake caused by a fault that offsets features on the Earth's surface may have an epicenter that does not lie on the trace of that fault on the surface. This occurs if the fault plane is not vertical and the earthquake occurs below the Earth's surface.

Fault: A break in the Earth along which movement occurs. Sudden movement along a fault produces earthquakes. Slow movement produces aseismic creep. Fault plane solution: The calculation of the orientation, dip, and slip direction of a fault that produced the ground motion recorded at seismograph stations. Sometimes called a focal mechanism solution.

Focus: The place in the Earth where rock first breaks or slips at the time of an earthquake; also called the hypocenter. The focus is a single point on the surface of a ruptured fault. During a great earthquake, which might rupture a fault for hundreds of kilometers, one could be standing on the rupturing fault, yet be hundreds of kilometers from the focus.

Hypocenter: See focus.

Intensity: A measure of the severity of shaking at a particular site. It is usually estimated from descriptions of damage to buildings and terrain. The intensity is often greatest near the earthquake epicenter. Today, the Modified Mercalli Scale is commonly used to rank the intensity from I to XII according to the kind and amount of damage produced. Before 1931 earthquake intensities were often reported using the Rossi-Forel scale.

Liquefaction: A process, in which, during ground shaking, some sandy, water-saturated soils can behave like liquids rather than solids.

Magnitude: A quantity characteristic of the total energy released by an earthquake, as contrasted with intensity, which describes its effects at a particular place. A number of earthquake magnitude scales exist, including local (or Richter) magnitude (M_L), body wave magnitude (m_b), surface wave magnitude (M_S), moment magnitude (M_w), and coda magnitude (M_c). As a general rule, an increase of one magnitude unit corresponds to ten times greater ground motion, an increase of two magnitude units corresponds to 100 times greater ground motion, and so on in a logarithmic series. Commonly, earthquakes are recorded with magnitudes from 0 to 8, although occasionally large ones (M=9) and very small ones (M=-1 or –2) are also recorded. Nearby earthquakes with magnitudes as small as 2 to 3 are frequently felt. The actual ground motion for, say, a magnitude 5 earthquake is about 0.04 millimeters at a distance of 100 kilometers from the epicenter; it is 1.1 millimeters at a distance of 10 kilometers from the epicenter.

Mainshock: The largest in a series of earthquakes occurring closely in time and space. The mainshock may be preceded by foreshocks or followed by aftershocks.

Mantle: A rock layer, about 2,894 kilometers thick, between the Earth's crust and core. Like the crust, the upper part of the mantle is relatively brittle. Together, the upper brittle part of the mantle and the crust form tectonic plates.

Modified Mercalli Intensity Scale: A scale for measuring ground shaking at a site, and whose values range from I (not felt) to XII (extreme damage to buildings and land surfaces).

NEHRP: The federal National Earthquake Hazard Reduction Program, enacted in 1977, to reduce potential losses from earthquakes by funding research in earthquake prediction and hazards and to guide the implementation of earthquake loss-reduction programs.

Normal fault: A normal fault can result from vertical motion of two adjacent blocks under horizontal tension. (It also occurs in rocks under compression if stress is unequal in different directions. In this case, the minimum and maximum compressive stresses must be applied horizontally and vertically respectively.) In a normal fault, the upper of the two adjacent blocks of rock slips relatively downward.

P (primary) waves: Also called compressional or longitudinal waves, P waves are the fastest seismic waves produced by an earthquake. They oscillate the ground back and forth along the direction of wave travel, in much the same way as sound waves, which are also compressional, move the air back and forth as the waves travel from the ground source to a sound receiver.

Plates: Pieces of crust and brittle uppermost mantle, perhaps 100 kilometers wide, that cover the Earth's surface. The plates move very slowly over, or possibly with, a viscous layer in the mantle at rates of a few centimeters per year.

Plate boundaries: The edges of plates or the junction between the plates.

Plate tectonics: A widely accepted theory that relates most of the geologic features near the Earth's surface to the movement and interaction of relatively thin rock plates. The theory predicts that most earthquakes occur when plates move past each other.

Return times: Sometimes called the recurrence time or recurrence interval. The return time, or more properly the average return time, of an earthquake is the number of years between occurrences of an earthquake of a given magnitude in a particular area. For example, if the average time of an earthquake having a magnitude greater than or equal to 7 is 100 years, then, on the average, such earthquakes will occur every 100 years. If such earthquakes occur randomly in time, there is always the chance that the actual time interval between the events will be less or greater than 100 years. Return time is best described in terms of probabilities. In the case of an earthquake having a 100-year average return time, there is about an 18 percent chance that such an earthquake will occur in the next 20 years and a 63 percent chance that it will occur in the next 100 years. On the other hand, there is a 14 percent chance that it will not occur in the next 200 years.

Reverse fault: A rupture that results from vertical motion of two adjacent blocks caused by horizontal compression. Sometimes called a thrust fault. In a reverse fault, the upper of the two adjacent blocks moves relatively upward.

Richter Magnitude scale: An earthquake magnitude scale, more properly called local magnitude scale, based on measurements of the amplitude of earthquake waves recorded on a standard Wood-Anderson type seismograph at a distance of less than 600 kilometers from the epicenter.

S (secondary or shear) waves: S waves oscillate the ground perpendicular to the direction of wave travel. They travel about 1.7 times slower than P waves. Because liquids will not sustain shear stresses, S waves will not travel through liquids like water, molten rock, or the Earth's outer core.

Seiche: A standing wave in a closed body of water such as a lake or bay. It can be characterized as the sloshing of water in the enclosing basin. Seiches can be produced by seismic waves from earthquakes. The permanent tilting of lake basins caused by nearby fault motions has produced very energetic seiches.

Seismic waves: A vibrational disturbance in the Earth that travels at speeds of several kilometers per second. There are three main types of seismic waves in the Earth: P (fastest), S (slower), and Surface waves (slowest). Seismic waves are produced by earthquakes.

Seismogram: A graph showing the motion of the ground versus time.

Seismograph: A sensitive instrument that can detect, amplify, and record ground vibrations too small to be perceived by human beings.

Site response: Local vibratory response to seismic waves. Some sites experience more or less violent shaking than others, depending on factors such as the nature and thickness of unconsolidated sediments and/or the configuration of the underlying bedrock.

Strike-slip fault: Horizontal motion of one block relative to another along a fault plane. If one stands on one side of the fault and observes than an object on the other side moves to the right during an earthquake, the fault is called a right-lateral strike-slip fault (like California's San Andreas fault). If the object moves to the left, the fault is called a left-lateral strike-slip fault.

Subduction zone boundary: The region between converging plates, one of which dives beneath the other. The Cascadia subduction zone boundary is an example.

Subduction earthquake: A thrust-type earthquake caused by slip between converging plates in a subduction zone. Such earthquakes usually occur on the shallow part of the boundary and can exceed magnitude 8.

Surface waves: Seismic waves, slower than P or S waves, that propagate along the Earth's surface rather than through the deep interior. Two principal types of surface waves, Love and

Rayleigh waves, are generated during an earthquake. Rayleigh waves cause both vertical and horizontal ground motion, and Love waves cause horizontal motion only. They both produce ground shaking at the Earth's surface but very little motion deep in the Earth. Because the amplitude of surface waves diminishes less rapidly with distance than the amplitude of P or S waves, surface waves are often the most important component of ground shaking far from the earthquake source.

Thrust fault: See reverse fault.

Transform boundary: A boundary between plates where the relative motion is horizontal. The San Andreas fault is a transform boundary between the North American plate and the Pacific plate. The Blanco fracture zone is a transform boundary between the Juan de Fuca and the Pacific plates.

Tsunami: A tsunami is a series of very long wavelength ocean waves caused by the sudden displacement of water by earthquakes, landslides, or submarine slumps. Ordinarily, tsunamis are produced only by earthquakes exceeding magnitude 7.5. In the open ocean, tsunami waves travel at speeds of 600-800 kilometers/hour, but their wave heights are usually only a few centimeters. As they approach shallow water near a coast, tsunami waves travel more slowly, but their wave heights may increase to many meters, and thus they can become very destructive.

World-Wide Standard Seismograph Network (WWSSN): A network of about 110 similarly calibrated seismograph stations that are distributed throughout the world. The network was originally established in the early 1960s, and its operation is now coordinated by the U.S. Geological Survey. Each station has six seismometers that measure vertical and horizontal ground motion in two frequency ranges.

II. Common Acronyms and Abbreviations

The following acronyms are used in this HMST Report:

CAO	Critical Areas Ordinance
CFR	Code of Federal Regulations
CRAB	County Road Administration Board
CREW	Cascadia Regional Earthquake Workgroup
CRS	Community Rating System
EIS	Early Implementation Strategies
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
GMA	Growth Management Act
HAZUS	Hazards United States
HMGP	Hazard Mitigation Grant Program
HMST	Hazard Mitigation Survey Team
IA	Individual Assistance (Program)
IBC	International Building Code
NEHRP	National Emergency Hazard Reduction Program
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPSC	National Processing Service Center
OSPI	Office of Superintendent of Public Information
PA	Public Assistance (Program)
SBA	Small Business Administration
SBCC	State Building Code Council
SSAC	Seismic Safety Advisory Committee
UBC	Uniform Building Code
USGS	United States Geological Survey
WSDNR	Washington State Department of Natural Resources
WSDOT	Washington State Department of Transportation
WSDSHS	Washington State Department of Social and Health Services
WSEMC	Washington State Emergency Management Council
WSEMD	Washington State Emergency Management Division
WSOCD	Washington State Office of Community Development
WSUTC	Washington Utilities and Transportation Commission
WWSSN	World-Wide Standard Seismograph Network

III. HMST Meeting Participants

Olympia HMST Meeting – April 24, 2001

Name	Organization
Craig Apperson	Office of Superintendent of Public Instruction
James Bela	Oregon/Washington Earthquake Awareness
Marty Best	Washington Emergency Management Division
Jeff Bowers	Federal Emergency Management Agency, Region 10
Sophia Byrd	Washington Association of Counties
Susan Callan	Federal Emergency Management Agency, Region 10
Robin Campbell	Washington Office of Financial Management
Mark Carey	Federal Emergency Management Agency, Region 10
Karen Caton	Federal Emergency Management Agency, Region 10
Dave Catterson	Association of Washington Cities
Tammi Clark	Washington Emergency Management Division
Kimberly Craven	Governor's Office of Indian Affairs
George Crawford	Washington Emergency Management Division
George Currin	Federal Emergency Management Agency, Region 10
Tim D'Acci	Washington Department of Ecology
Bob Freitag	University of Washington, Institute for Hazard Mitigation
Lorri Hergert	Washington Emergency Management Division
Eric Holdeman	King County Emergency Management Division
Patty Linehan	Washington House of Representatives
Doak Mahlik	Federal Emergency Management Agency, Region 10
Luke Meyers	Washington Emergency Management Division
Diane Offord	Washington Emergency Management Division
Ines Pearce	Seattle Office of Emergency Management
Robert Purcell	Federal Emergency Management Agency, Region 10
Joan Scofield	Washington Office of Insurance Commissioner
Dennis Sigrist	Oregon Emergency Management
Dodie Simpson	Washington Office of Superintendent of Public Instruction
Dave Spicer	U.S. Army Corps of Engineers
Tim Walsh	Washington Department of Natural Resources
John Wheeler	Clark Regional Emergency Services Agency
Glen Woodbury	Washington Emergency Management Division

Everett HMST Meeting - April 26, 2001

Name	Organization
Sharon Atkinson	Congresswoman Jennifer Dunn’s Office
James Bela	Oregon/Washington Earthquake Awareness
Marty Best	Washington Emergency Management Division
Shawn Bliss	City of Bellevue

Name	Organization
Jeff Bowers	Federal Emergency Management Agency, Region 10
Steve Brown	City of Seattle
Mark Carey	Federal Emergency Management Agency, Region 10
Karen Caton	Federal Emergency Management Agency, Region 10
Tammi Clark	Washington Emergency Management Division
Carl L. Cook	Federal Emergency Management Agency, Region 10
George Crawford	Washington Emergency Management Division
George Currin	Federal Emergency Management Agency, Region 10
Tim D'Acci	Washington Department of Ecology
Dave DeHaan	Everett Fire Department
Claudia Ellsworth	Project Impact Pierce and King County
Chuck Hagerhjelm	Washington Emergency Management Division
T. J. Harmon	Island County Department of Emergency Management
Lorri Hergert	Washington Emergency Management Division
Mike McCallister	Snohomish County Department of Emergency Management
Luke Meyers	Washington Emergency Management Division
John Paul	U.S. General Services Administration
Richard Schroedal	Pierce County Department of Emergency Management
Thomas Sheahan	Skagit County Department of Emergency Management
William R. Trailor	Sauk-Suiattle Tribe
Tim Walsh	Washington Department of Natural Resources
Merrie Waylett	Federal Emergency Management Agency, Region 10

Yakima HMST Meeting - April 30, 2001

Name	Organization
Marty Best	Washington Emergency Management Division
Jeff Bowers	Federal Emergency Management Agency, Region 10
Mark Carey	Federal Emergency Management Agency, Region 10
Karen Caton	Federal Emergency Management Agency, Region 10
Tammi Clark	Washington Emergency Management Division
Roberta Clark	Federal Emergency Management Agency, Region 10
George Crawford	Washington Emergency Management Division
George Currin	Federal Emergency Management Agency, Region 10
Tim D'Acci	Washington Department of Ecology
Jonathan DeVaney	Congressman Doc Hasting’s Office
Charles Erwin	Yakima Valley Emergency Management
Rick Garza	Benton County Emergency Services
Lorri Hergert	Washington Emergency Management Division
Luke Meyers	Washington Emergency Management Division
Keith Stringfellow	Chelan County Emergency Management
Anton (Tony) Wentz	Yakima Valley Emergency Management

IV. HMST Report Team Members

WASHINGTON STATE EMERGENCY MANAGEMENT DIVISION

Martin Best	Deputy State Coordinating Officer – Mitigation
Tammi Clark	Emergency Management Program Assistant
George Crawford	Washington State Earthquake Program Manager
Tim D'Acci	National Flood Insurance Program Coordinator, Washington State Department of Ecology
Lorri Hergert	Emergency Management Program Coordinator
Luke Meyers	Emergency Management Program Assistant
Diane Offord	State Coordinating Officer
Tim Walsh	Chief Geologist-Environmental, Washington State Department of Natural Resources

FEDERAL EMERGENCY MANAGEMENT AGENCY

Jeff Bowers	Mitigation Program Delivery Branch Chief
Susan Callan	Mitigation Technical Writer
Mark Carey	Co-Deputy Federal Coordinating Officer – Mitigation
Karen Caton	Mitigation Technical Writer
Carl L. Cook Jr.	Deputy Federal Coordinating Officer – Mitigation
Diane Earl	Mitigation Success Story Project Lead
Jason Greenlee	Mitigation Technical Writer
Bruce Knipe	Federal Hazard Mitigation Officer
William Lokey	Federal Coordinating Officer